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This is second issue of volume three of International Journal of Human Computer Interaction (IJHCI). IJHCI is an International refereed journal for publication of current research in Human Computer Interaction. Publications of IJHCI are beneficial for researchers, academics, scholars, advanced students, practitioners, and those seeking an update on current experience, state of the art research theories and future prospects in relation to applied science. Some important topics covers by IJHCI are affective computing, agent models co-ordination and communication, computer mediated communication, innovative interaction techniques and user interface prototyping for interactive systems etc.

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Interface on Usability Testing Indonesia Official Tourism Website

A. Ramadona Nilawati *rama@staff.gunadarma.ac.id*
Faculty of Industrial Engineering
Gunadarma University
Margonda Raya No.100, Depok, West Java, 16424

Dewi Agushinta R. *dewiar@staff.gunadarma.ac.id*
Faculty of Computer Science and Information Technology
Gunadarma University
Margonda Raya No.100, Depok, West Java, 16424

Anindito Yoga Pratama *aga.ti_92@student.gunadarma.ac.id*
Informatics Engineering Department
Gunadarma University
Margonda Raya No.100, Depok, West Java, 16424

Dea Adlina *dea.adlina_ti@student.gunadarma.ac.id*
Informatics Engineering Department
Gunadarma University
Margonda Raya No.100, Depok, West Java, 16424

Nadia Rahmah Al Mukarrohmah *n4dh1_ch4n@student.gunadarma.ac.id*
Informatics Engineering Department
Gunadarma University
Margonda Raya No.100, Depok, West Java, 16424

Abstract

Ministry of Tourism and Creative Economy of The Republic of Indonesia must meet the wide audience various needs and should reach people from all levels of society around the world to provide Indonesia tourism and travel information. This article will gives the details in the evolution of one important component of Indonesia Official Tourism Website as it has grown in functionality and usefulness over several years of use by a live, unrestricted community. We chose this website to see the website interface design and usability and to popularize Indonesia tourism and travel highlights. The analysis done by looking at the criteria specified for usability testing. Usability testing measures are the ease of use (effectiveness, efficiency, consistency and interface design), easy to learn, errors and syntax which is related to the human computer interaction. The purpose of this article is to test the usability level of the website, analyze the website interface design, and provide suggestions for improvements in Indonesia Official Tourism Website of analysis we have done before.

Keywords: Interface, Usability, Website.

1. INTRODUCTION

The wide variety of existing information and the rapid development of information technology have made many web based application products and services available for daily use. Information distribution can be done by improving knowledge access and transferring knowledge by using media such as website.

Websites are used daily for reading news, finding work vacancy, shopping, finding telephone information, ordering food, planning for a trip, selling products and even helping a company business processes. Services concerning customers such as customer care in a company, internet banking service, online reservation service, product promotion and marketing, project management or even e-learning are the examples of many services using web based application. Interface development for tourism website must actively involving user from planning trough evaluation. If a user feels uncomfortable in using an application or a product or a service then it can be assumed that it is difficult to use and has the potential to be a failure. If a website is a failure then there will be a certain loss in all of the money spent in the development of the website, loss in reaching market success, user disappointment, trip plans cancelation, bad image and business process disturbance.

One way to evaluate an interface is usability test. Usability test is measuring the ease of use, easy to learn, errors and syntax. There are many methods on doing a usability test such as formal usability test. Formal usability test in Indonesia Official Tourism Website interface is done in order to know Indonesia Official Tourism Website usability, to identify the problems found by user when using Indonesia Official Tourism Website, and to know the changes that have to be applied in Indonesia Official Tourism Website. Criteria used for the usability test are ease of use, easy to learn (terms used, system speed, time, and consistency), errors and syntax in Indonesia Official Tourism Website.

2. LITERATURE REVIEW

2.1 Human Computer Interaction

Sometimes called as Man-Machine Interaction or Interfacing, concept of Human-Computer Interaction / Interfacing (HCI) was automatically represented with the emerging of computer, or more generally machine, itself. The reason, in fact, is clear: most sophisticated machines are worthless unless they can be used properly by human. This basic argument simply presents the main terms that should be considered in the design of HCI: functionality and usability [1].

Why a system is actually designed can ultimately be defined by what the system can do i.e. how the functions of a system can help towards the achievement of the purpose of the system. Functionality of a system is defined by the set of actions or services that it provides to its users. However, the value of functionality is visible only when it becomes possible to be efficiently utilized by the user [2]. Usability of a system with a certain functionality is the range and degree by which the system can be used efficiently and adequately to accomplish certain goals for certain users. The actual effectiveness of a system is achieved when there is a proper balance between the functionality and usability of a system [3].

Having these concepts in mind and considering that the terms computer, machine and system are often used interchangeably in this context, HCI is a design that should produce a fit between the user, the machine and the required services in order to achieve a certain performance both in quality and optimality of the services [4].

Thus HCI is mainly concerned with the development of human capabilities to use machines, the designing and building of interfaces, process optimization between man and machine, interface usability, and better communication between man and machine. Whereas HCI studies the interaction of man and machine together, and usability studies ensure its effectiveness. Application of HCI in technology results in usability, universality, and usefulness [2]. Usability is a quantitative and qualitative measurement of the design of a user interface, grouped into five key factors: learn ability, efficiency, memorability, errors, and satisfaction [3].

2.2. Usability

Usability is a term used to indicate that people can employ a particular tool with ease in order to achieve certain goals. Usability can also refer to the method used to measure the usability and the study of neatness or efficiency of an object.

There are many usability methods and principles that exist such as usability inspections methods and discount usability methods [5], formative and summative usability evaluations [6]. These methods usually may also accompany think-a-loud protocols and competitive analysis. In any usability evaluation, there are always discussions regarding how many users are enough for a test. A study by Nielsen [3] further suggests that five users are enough. Research by Faulkner [7] suggests that as many as 85% of usability problems but that as few as 55% could be found as well with using only five users. With increasing the number of users to 15, the range of problems found can be 90-97%.

Dimension Usability

Usability dimensions which are classified Whitney Quesenbery [8], as follows:

a. Effective : How completely and accurately the work or experience is completed or goals reached.
b. Efficient : How quickly this work can be completed.
c. Engaging : How well the interface draws the user into the interaction and how pleasant and satisfying it is to use.
d. Error tolerant : How well the product prevents errors and can help the user recover from mistakes that do occur.
e. Easy to learn : How well the product supports both the initial orientation and continued learning throughout the complete life time of use.

Component Usability

Usability is defined by 5 quality components [9]:

a. Easy to learn : How easy is it for users to accomplish basic tasks the first time they encounter the design?
b. Efficiency : Once users have learned the design, how quickly can they perform tasks?
c. Memorability : When users return to the design after not using it for a certain period, how easily can they reestablish proficiency?
d. Errors : How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
e. Satisfaction : How pleasant is it to use the design?

2.3. Interface Design

Advance interface design has the following characteristics [10]:

a. Standardization : The uniformity of the properties of user interfaces in different applications.
b. Integration : Integration of packaged applications and software tools.
c. Consistency : Uniformity in the application program.
d. Portability : The possibility to convert data in a variety of hardware and software.

There are several things that cause reduced levels of usability of an interface design system, among them are:

- Text is not clear and precise which will cause doubt; this will make the user needs to re-read and allows a false interpretation.
- Graphics are not precise that important elements are hidden.
- Title misrepresents the content. This creates confusion and hinders the ability to view the existing relations.

- Requests for information that is unimportant or irrelevant. Information requests require user to remember the previous answers that will confuse users which in turn lead to errors.
- Layout is unstructured and undirected that allow the occurrence of errors.
- Poor quality of presentation that will cause difficulty in reading which would disturb the user and cause error.

3. METHODOLOGY

In this research, testing was conducted by analyses performed. Analyses performed in accordance with the tested usability criteria include:

- Ease of use
- Easy to learn (terms used, system speed, time, and consistency)
- Errors in the Indonesia Official Tourism Website
- The syntax that should be used in Indonesia Official Tourism Website.

From the analysis done by looking at the criteria specified for testing, we will give advice(s) in accordance with the results that we have processed from testing.

4. RESULT AND DISCUSSION

The official website of Ministry of Tourism and Creative Economy of The Republic of Indonesia is www.indonesia.travel [11]. The discussion is started by general analysis of website's usability and interface design followed by detail analysis by dividing the website into three parts: header, sidebar and body and special functionality such as link, navigation, and graphic design.

4.1. General Analysis

At a glance, the website usability and design of website is satisfactory; however, this website has many drawbacks. The following will discuss those drawbacks in detail including suggestion(s) for each drawback.

The first drawback is on the language box. The function of the language box in the upper left corner is to change the language of the website; however it refers to a different website URL instead. Figure 1 will show the difference of interface on several languages.

http://www.indonesia.travel/en http://www.visitindonesia.jp/

http://www.visit-indonesia.com.cn/

http://www.tourisme-indonesie.fr/

FIGURE 1: Indonesia tourism and travel in English, Japanese, Chinese and French.

Suggestion:
It will be better if the website interface is keeping its consistency so that change of language will not change website interface format.

Note: Although there are many different URL based on changes in language, the discussion is focused on analyzing only the English website.

The second drawback is the home page length. Because of the insertion of wide variety of features such as featured destination, quick activities on destination info, video, news, calendar, facebook, and twitter screenshots and various links, the home page became too long.

Suggestion:
Although all of the included features are important, it will be better if:

- **News and link** are shown in slides so it would not use too much space.
- **Calendar** is not present on the home page but on each tourism area (province or town) so it will only show events on certain date that will occur only in the specified tourism area.
- **Facebook** and **twitter** link presented only in icons rather than writings and screenshots.

The third drawback is within the gallery. The gallery is poorly organized and there are repeated, blurry, low resolution, unattractive and pictures in the gallery.

Suggestion:

- Putting pictures of animals, plants, landscapes and civilians activity in their own group. This will help user to directly choose pictures based on their preference.
- Paying more attention to picture resolution and size so the gallery will have a standard and makes it looks tidier, interesting and professional.

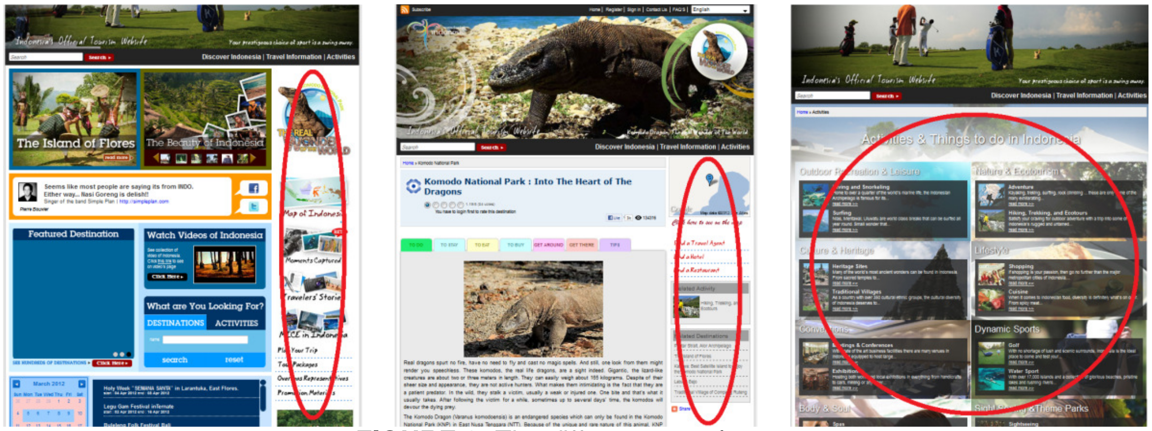

FIGURE 2: The different page layout.

The fourth drawback is the website layout inconsistency. For instance, when opening a different page, the sidebar changes or removed and there is no link to go back to the homepage.

Suggestion:
The website should keep its consistency by making the layout for all pages similar.

4.2. Detailed Analysis

As shown in figure 3, the website is divided into three parts: header, sidebar and body. The following will provide the analysis of each part.

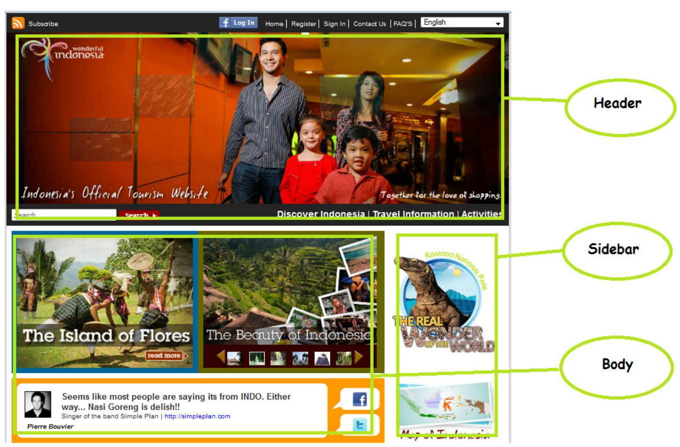

FIGURE 3: Website division.

Header
The drawbacks on the website's header are too small and hard to find title, unstructured links position and unrelated elements that do not have a clear group category are located nearby. These drawbacks are shown in Figure 4.

Suggestion:

- Title is important in helping visitors to obtain information of the website. It will be better if the size of title is bigger, so it will be easy to see.
- Organizing the links based on their relevance. In example, the link **home** should be located beside Discover Indonesia etc.

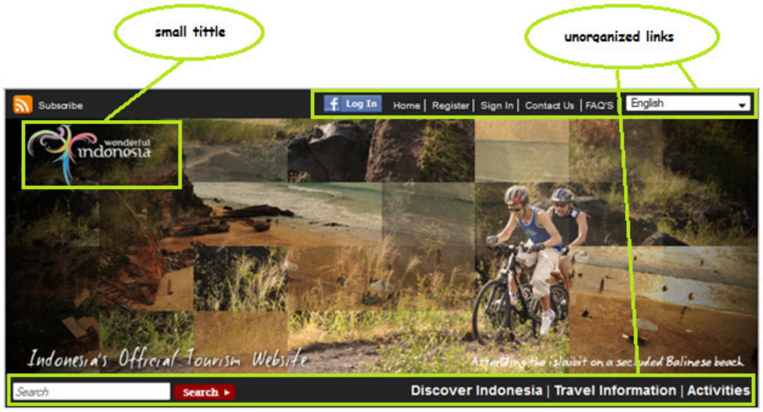

FIGURE 4: The drawbacks of the header.

Sidebar
In the sidebar, there are many icons, pictures and texts that contain a link. When the cursor points those items the appearance becomes fade, indicating that they contain the link to another page; However, as shown in Figure 5, some pictures do not do the same, for instance, their color do not change. The grouping is well organized but the arrangement is not in order.

Suggestion:

- Make the entire item that contains link change when pointed by the cursor, for instance blinking, fading or enlarging. This will help the visitor knows that it will bring them to other page when clicked.
- Rearrange the groups of items based or their importance. The most important group is placed in the uppermost part, for example, placing find us on facebook or twitter in the bottom.

FIGURE 5: An icon that change (left) and icon that does not change (right).

Body
The drawbacks on the body are too many contents, not well organized contents, unclear element separation and relation, and no group for related contents. The drawbacks in the news page are the news content has many paragraphs but lack of highlight that makes it look like a book; the color of each box does not match for example, the box “Beauty of Indonesia” is green while the others are blue and orange and color gradation does not have enough contrast.

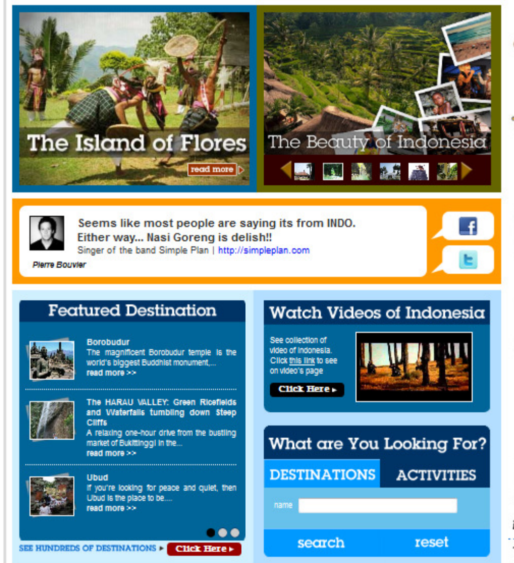

FIGURE 6: The drawbacks of body.

Suggestion:

- Make the page tidier and more structured by organizing the contents, grouping the contents which are related, and splitting the groups by giving space, line or border.
- Many users find reading from the monitor slower and more awkward than from paper. To help user in this matter the website should have shorter paragraph with more highlights and symbols.
- Choose matching colors for the webpage. Making it contrast to attract visitors.

5. CONCLUSION AND RECOMMENDATION

The high usability and attractive graphic design of a webpage give an important role to increase a website quality. A webpage design must be user oriented, it is important to know what kind of user that will visit the website. To know this, studies in users need are required. The analysis above can be concluded that generally, the website is good although it has several weaknesses in design and functionality.

In order to make a website better, study of usability and graphic design of a website is required. For Indonesia tourism and travel website the following improvements are necessary: Making each page layout consistent, Choosing the right color, Organizing the position, Grouping related items, and Using highlight and symbol instead of text.

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Monitoring and Visualisation Approach for Collaboration Production Line Environments: A Case Study in Aircraft Assembly

Ilkka Niskanen *Ilkka.Niskanen@vtt.fi*
Digital Service Research
VTT Technical Research Centre of Finland
Oulu, 90571, Finland

Julia Kantorovitch *Julia.Kantorovitch@vtt.fi*
Digital Service Research
VTT Technical Research Centre of Finland
Espoo, 02150, Finland

Jerome Golenzer *Jerome.Golenzer@eads.net*
EADS Innovation Works
Toulouse, 31000, France

Abstract

In this paper, the SPMonitor tool, which is designed to monitor and visualise run-time execution of productive processes, is proposed. SPMonitor enables the dynamic visualisation and monitoring of workflows running in a system. It displays versatile information about currently executed workflows, thus providing a better understanding of processes and the general functionality of the domain. Moreover, SPMonitor enhances cooperation between different stakeholders by offering extensive communication and problem-solving features that allow the actors concerned to react more efficiently to different anomalies that may occur during a workflow execution. The ideas discussed are validated through a real-life case study related to aircraft assembly lines.

Keywords: Collaboration, Productive Lines, Workflow, Monitoring, Visualisation.

1. INTRODUCTION

The field of computer-supported collaboration work is often associated with office work. However, industrial production lines such as products assembly lines are highly relevant as a case for this research field. Several issues are involved considering the complexity of products manufactured:

- In such processes, various teams with different areas of technical expertise are involved in activities to be performed synchronously. These activities are not always sequential.
- There is an increasing complexity of subsystems to assemble, along with the fact that supply components come from various industry parties and players.
- One activity in the process may influence another, therefore the coordination is required.
- There is heterogeneous information all over the shop floor and interdependencies exist within the information spaces.
- There are external factors impacting operational status, such as unavailable or multifunctional equipment, delay in supplier components or changes in the human resources involved.

In addition, tight deadlines and a reduction in the time-to-market place additional pressure on the organisation and monitoring of working processes towards their productivity and the quality of the final product.

The design and development of modelling and analytical techniques of the production lines was the subject of extensive study in the past. The use of commercial digital mock-up systems (DMU) enabling different visual qualities and functions are becoming more common [1][2][3]. However, effective real-time progress monitoring tools supporting DMUs are still immature.

The complexity of modern production lines and the dynamic nature of the domain make it difficult to maintain the 'As-Planned' progress during the actual execution (e.g. discrepancies and frequent changes). This results in schedule and cost overruns, which accordingly call for the efficient monitoring and coordinating interfaces with the production process, which is able to provide a real-time view of the current state of processes and relevant attributes ('As-Is' view).

Existing coordination solutions developed and reported in the literature so far are mainly based on public interactive displays. The andon system [4] made famous by Toyota is simply a way of reporting the occurrence of a problem on the assembly line ('andon' is the Japanese for 'signal'). In case of a problem, the operator pulls an alarm cord and an electronic board is activated. Early projects, such as LiveBoard [5], focused on supporting collaborative activities through large electronic whiteboards using novel interaction techniques. Later on, this work was extended in recent projects by embedding several interconnected displays in the environment to support more complex collaboration activities, including Trauma's center Whiteboard [6] iLand [7] and iRoom [8]. From an application point of view, the closest to our research is a study presented by [9] targeting user acceptance issues in the environment composed of large public displays to facilitate the collaborative process in the aircraft final assembly lines in Toulouse. There are also other applications that have exploited large displays to make information on activities available to a community of users.

These systems are developed with the objective of supporting a broad spectrum of group activities, creating a common information space and providing the background awareness on activities that a number of various groups/teams are involved in and tasks that have been accomplished. However, for a productive assembly project, as-built progress or DMU should be constantly monitored and compared with as-planned assembly progress, and real-time prompt corrective actions should be taken in case of observational discrepancies. Current tools such as graphs, charts and photos may not facilitate the communication of progress and ensure corrective action is taken clearly and quickly enough. More advanced means aiming at anticipating problems like overlaps of assembly parts and proposing corrective actions in an intuitive and promptly intelligible way are still lacking.

Based on the aspects discussed above and through the exploitation of the close cooperation with the EADS R&D team in the European Smart Products project [10], this paper presents a novel approach to support the collaboration of various actors involved in the processes related to production line environments.

Leveraging recent advances in semantic technologies, 3D visualisation techniques and contextual workflow modelling mechanisms, SPMonitor provides intuitive and convenient visual aids to support various actors involved in overall processes running on industrial production lines. By managing the interdependencies between numerous activities running concurrently, it aims to provide support for the combining, storage and distribution of various statuses, scheduling information, tasks, the usage of resources and tools, and updates providing contextual views to operators, support teams and managers responsible for the overall processes on the line. The combination of interaction means and interface elements to run-time environment and DMU facilitate the ability of the tool to quickly sort and display the performance metrics and deviations, possible unexpected events and anomalies in order to highlight the high priority requirements and actions required for recovering from errors and assembling resources.

In addition, from a scientific point of view, this research contributes with the novel approach of semantically annotated contextual workflow-based production process description. Semantically described workflows provide powerful reasoning potential to align information spaces of productive lines and enable richer visualisations showing comprehensive data in a single view. The ontologies used to describe workflows, environmental features and sensory perception devices can be flexibly extended. With new plug-in domain-specific ontologies, the tool can support additional application domains.

Moreover, the visualisation layer of semantically defined workflow descriptions supporting real-time progress monitoring is proposed. Various contextual views empowered by 3D functional graphic elements provide the value for the coordination and control of production lines. The visualisation libraries can be extended with domain-specific needs.

This paper is divided into six sections. Section 2 presents the background of the application domain for our study and the most important requirements that guided the development of the SPMonitor. Section 3 details the design and implementation of the tool. The run-time execution of SPMonitor and experiments that were accomplished to validate the prototype are described in Section 4. Section 5 provides the initial evaluation results performed by researchers and domain experts to measure the usability and perceived usefulness of the tool. Finally, Section 6 presents the conclusions drawn from the research project.

2. CONTEXT AND REQUIREMENTS

On an aeronautical final assembly line, the aircraft goes through several stages before completion. The process is often not sequential: several operator teams can be involved at the assembly station. Apart from operators performing assembly tasks, there are also support teams and a manager. The support teams help operators to solve operational problems and verify the technical issues, deal with logistics and ensure that the necessary tools are available for operators. The manager is responsible for the overall process of assembly and is also able to take action in cases where discrepancies are detected. Paper-based coordination between various actors is still used on the lines. Operators facing a problem or needing to validate an operation have to walk over to the support offices, write a report and verbally notify the appropriate support person. This all takes time.

In our context, the realistic scenario provided by EADS for research purposes involves two operators who have received a work order to tighten two electric harnesses onto an aircraft panel. Both operators work simultaneously on the same work order, which may contain several sub-tasks. The operators are also equipped with tools, a nomadic device and a smart tool (e.g. a smart rivet gun, a smart glue gun or a screwdriver). The nomadic device guides the worker through the workflow and the smart tool is used to tighten assemblies. The scenario also includes a support team that monitors the assembly procedure remotely and reacts in case of unexpected events during the process, and a station manager who is in charge of the overall organisation of the assembly line. More information about the background to the scenario can be found in [11] [12].

The main purpose of SPMonitor is to support cooperation between different actors in the scenario. First of all it should provide better understanding about work processes by representing an up-to-date visualisation of the current state of the assembly process. Besides visualising work processes, SPMonitor should be able to show illustratively the possible anomalies that may occur during a workflow execution and help the support team to react more efficiently to the problems. Moreover, SPMonitor is supposed to be used as a collaborative tool to exchange information between operators and the support team when resolving anomalies. Finally, SPMonitor can be utilised in the subsequent diagnosis, in which the support team and the station manager analyse the workflow performance data and any possible anomalies in cooperation.

3. DESIGN AND IMPLEMENTATION

Based on the context and requirements discussed previously, an approach that supports the collaborative visualisation of assembly processes was built. SPMonitor contains three main building blocks: a workflow management system, communication middleware and monitor software. The role of the workflow management system is to manage and execute processes and provide the necessary information for external applications. The communication middleware intermediates, either remotely or locally, between data from different components, and finally, the monitor software implements functionalities required for workflow monitoring. Figure 1 represents the compositional structure in more detail.

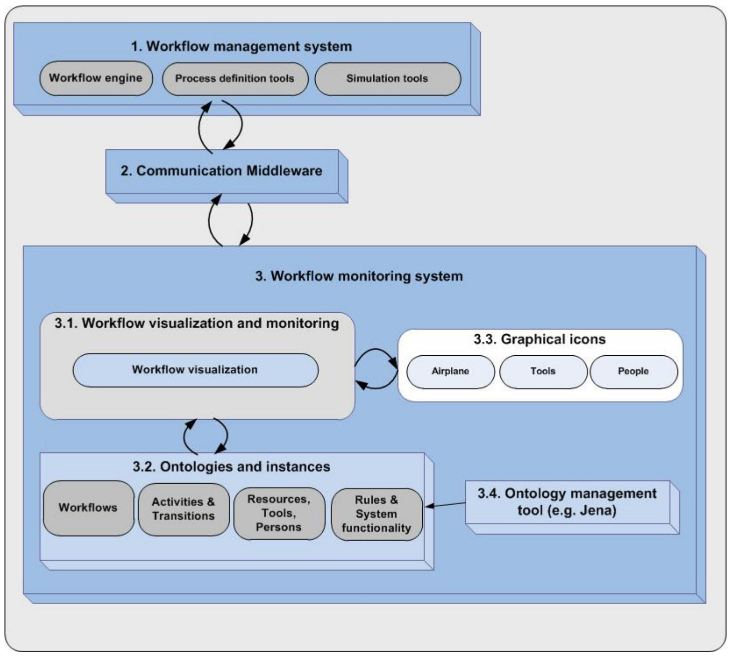

FIGURE 1: FMC block diagram of the SPMonitor components

The different components are described below in more detail:

- **Workflow management system** contains software tools for designing, defining and executing workflows. Additionally, it provides the necessary data for workflow monitoring using publish/subscribe mechanisms, for example.
- **Communication middleware (API)** acts as an intermediary between workflow management and monitoring systems. Moreover, it provides a means to remotely discover different components in the line system. Mundocore middleware [17] is used to provide the communication infrastructure for the information exchange in the line.
- The **workflow monitoring system** realises the different functionalities needed for semantically modelling and visualising different processes and reacting to anomalies. The main parts of the workflow monitoring system:
    - **Workflow visualisation and monitoring** is a core component of the system. It provides mechanisms for visualising workflows and other related information, as well as possible anomalies. Additionally, it implements the different interactive elements needed, for example, for managing anomalies.
        - The **ontologies and instances** component is a semantic library represented by ontologies which contains a workflow-related knowledge base. This component hosts the semantically

modelled workflow descriptions that are visualised with the monitor tool. It may also contain other semantically modelled information, such as rules and data describing different resources that are associated with workflow activities.

- **Graphical Icons** provide visualisation libraries containing domain-specific 3D icons that are used in workflow visualisations
- The **ontology management tool** allows querying and updating ontology instances.

3.1 Semantic Workflow Data Model

One of the requirements that arose in the scenario was enabling the integration of heterogeneous workflow-related information into a single data model, which in turn facilitates more sophisticated data analysis and diagnostics capabilities through automatic reasoning and richer query opportunities, for example. The diverse work process data includes information such as activities, transitions, resources (e.g. people, tools), restrictions (e.g. deadlines, required skill levels) and preconditions. Semantic technologies play an important role in realising this requirement as they allow describing workflow activities, transitions and resources in a semantically rich form, and additionally, they provide powerful reasoning potential [29]. The data fusion capabilities also enrich the visualisations because the integration of data from multiple sources increases the amount of available workflow information, thus leading to more comprehensive visual representations.

As explained above, SPMonitor acquires non-semantic workflow information from a workflow engine and converts it into semantic form. Currently there are several [20][21][22] usually domain dependent approaches that define ontologies for semantically describing workflows. Moreover [19] defines a semantic workflow language OWL-WS (OWL for Workflow and Services) and a specific semantic workflow representation model for describing dynamic work processes that also enable the specification of higher-order workflows.

However, for this study it was decided to design a new workflow ontology that adopts some elements from the existing approaches but is especially adapted and optimised for visualisation and monitoring purposes. This more lightweight and flexible ontology is unencumbered by the burden of providing a means for workflow task processing. On the other hand, the defined ontology structure offers enough expressiveness to allow for the performing of sophisticated diagnosis and analysis operations. Additionally, the workflow ontology is general enough to be able to address various problem domains. The specified ontology was influenced by our earlier work on designing expandable ontologies for facilitating heterogeneous data integration for data mining and visualisation purposes [24].

The ontology specified in this study defines concepts, relationships and attributes needed for describing workflows and other related information. This workflow ontology holds the class and property definitions of the entities that the SPMonitor workflow models are built on. The class hierarchy of the workflow ontology is presented in Figure 2.

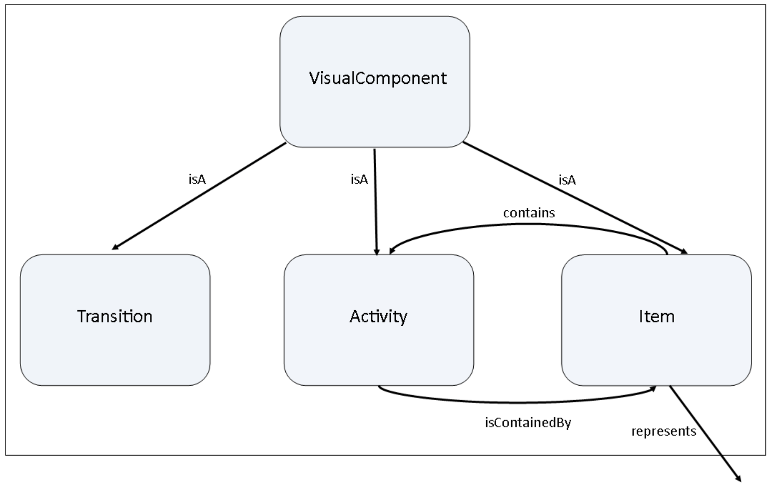

FIGURE 2: Context taxonomy

The main class of the workflow ontology is 'VisualComponent', which is divided into three subclasses – 'Transition', 'Activity' and 'Item'. The class 'Transition' represents transitions that link different activities together. For each transition an ID, a source activity and a destination activity must be determined. Additionally, a transition may have a type property, which describes the type of relationship between source and destination activities. Possible type values for transition are "otherwise", "condition", "default exception" and "exception". The class 'Activity' represents different steps or tasks of a workflow. Each activity instance defines its own ID and state values. The possible state values for activities are "not started", "open - running" and "closed – completed". Moreover, an activity may hold some additional properties such as resource requirements or time constraints. The third sub-class, 'Item", refers to entities that are contained by an activity. A typical item may be an operator that is assigned to a certain activity. Items may also have their own property values describing them in more detail.

SPMonitor forms semantic descriptions of workflows according to the ontology presented above. These models are dynamically updated each time a workflow management system sends an event message informing of activity state changes or anomaly occurrences, for example. The semantic workflow models are saved as OWL [23] files that can be used by other applications or opened with SPMonitor to be visualised or analysed later. Although the presented ontology is quite concise, its true power resides in its expandability. The ontology can be extended by integrating "plug-in" ontologies into it. This can be carried out through sub-classing or mapping concepts together with the 'owl:sameAs' statement, for example. With these plug-in ontologies, the tool can be adapted to support multiple different problem domains or integrated with other existing workflow ontology definitions.

3.2 Interactive Visualisation

The support for the enhanced understanding of work processes was released by designing illustrative and transparent workflow visualisation views that give a good overall representation of the data, and also provide the opportunity to acquire more detailed information on demand. Effective visualisation approaches enable humans to observe, manipulate, search, navigate, explore, filter, discover, understand and interact with data rapidly and effectively, to discover hidden patterns [30][31]. Moreover, interactive visualisation allows for the examination of the presentation of data on the fly from different perspectives and angles, helping the end user to understand the results of analysis and information retrieval better [13]. Thus, the different visualisation schemes were implemented to allow users to see various aspects of monitored workflows with different levels of abstraction and to interact extensively with the data being visualised.

The visualisation of workflows in SPMonitor is based on the Model-View-Controller (MVC) framework, which is a widely used architectural approach for interactive applications. The framework is successfully utilised earlier in the interactive visualisation of semantic context data, for example [25]. The Model-View-Controller framework divides functionality between objects involved in maintaining and presenting data to minimise the degree of coupling between the objects [14]. In the Model-View-Controller architecture, objects of different classes take over the operations related to the application domain (the model), the display of the application's state (the view), and the user interaction with the model and the view (the controller) [15].

The modularity of components has enormous benefits, especially when building interactive applications. Isolating functional units from each other as much as possible makes it easier to understand and modify each particular unit, without having to know everything about the other units. This three-way division of an application entails separating the parts that represent the model of the underlying application domain from the way the model is presented to the user and from the way the user interacts with it [15].

SPMonitor presents a novel way of visualising semantically defined workflow descriptions by providing four distinct views to examine models: a general view, a text view, a 2D view and an isometric view. In the following, each of the four views is described in more detail.

- **General view** gives a general picture of the overall situation. It shows the workflows that a currently active in a workflow management system and their current states.
- **TextView** provides a representation of a workflow model as it is written in OWL format. The view allows examining a workflow model in a textual form enabling also to discover the hidden workflow data that cannot be visually represented.
- **2DView** represents activities and transitions of a workflow in a “ground plan” like view. Activities are visualised as squares that are connected by transitions and the colour of the squares indicate the state of different activities. Similarly, the types of transitions are presented using colour codes. The purpose of the 2D view is to provide a better general insight of a workflow. In general, 2D views are considered better for navigating, establishing precise relationships and performing spatial positioning [16][17].
- **Isometric view** builds a visual representation of workflows from an isometric perspective. The visualisation provides a general picture of the monitored workflow and additionally it allows for the integration of varied workflow-related information within a single view perspective. For example, a visualisation of an activity defining an assembly task may include icons that represent the operator that is assigned to that activity or tools that are needed for executing the assembly task.

4. RUN-TIME EXECUTION

During the assembly process where several working processes are running in the background, a support team may examine the situation and select a workflow to be monitored. SPMonitor acquires the necessary information from the workflow management system and forms a semantic model of that workflow. To enable the dynamic monitoring of a selected workflow, the workflow management system notifies SPMonitor of different changes in the workflow execution data. For example, each time a monitored workflow proceeds from one activity to the next, a notification is sent to SPMonitor and the views are updated accordingly. The sequence diagram shown in Figure 3 illustrates the monitoring of workflows with SPMonitor in more detail.

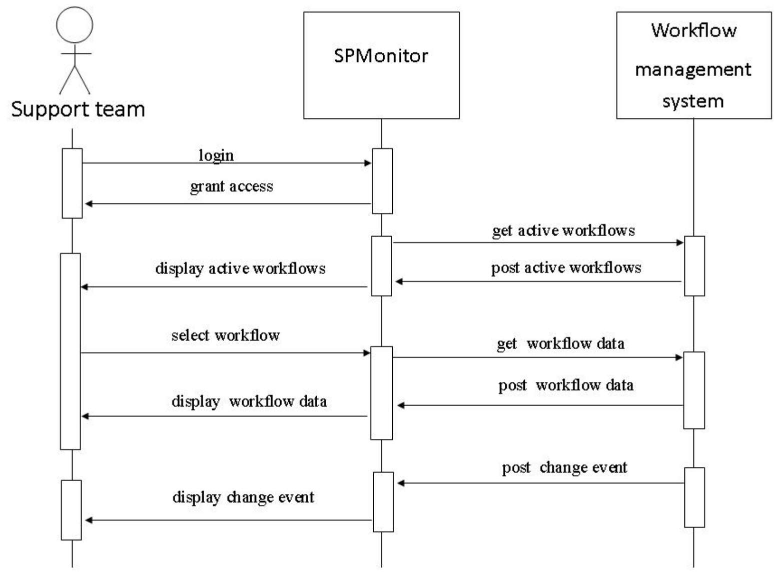

FIGURE 3: A sequence diagram of workflow monitoring

As previously discussed, SPMonitor contains three different views to visualise a single workflow. A graphical representation of the workflow model illustrates the different activities and transitions that are contained in the monitored workflow. The support team has also the opportunity to acquire additional information about a single activity by browsing for it. The opened information dialogue contains such information as work order name, operator performing task, state of activity, and possible sub-flow and sequence order of the selected activity. The status of different activities is indicated with the use of colours. The light blue colour means that the status of an activity is “not started”, a darker blue colour indicates that an activity is currently in the state “open - running” and the darkest blue shade symbolises the “closed – completed” state. Finally, if an activity is red, it means that an anomaly has occurred during the execution of that activity.

The different transitions are also indicated using colours. For example, a conditional transition is represented using yellow and an activity that is only entered in the case of an anomaly is interlinked with a red transition. If a transition does not have a type property, it is coloured grey. Figure 4 represents a screenshot from SPMonitor in which the workflow of the assembly case is visualised. The 2D view is shown in the upper panel and the isometric visualisation is represented in the lower part of the picture. As can be seen, the 2D view provides a more general picture of the monitored workflow, showing all the activities and transitions within a single view, whilst offering zoom in and zoom out functionalities. The isometric view represents a more detailed view of the workflow, populating different activities with icons that represent the operators and tools assigned to those activities.

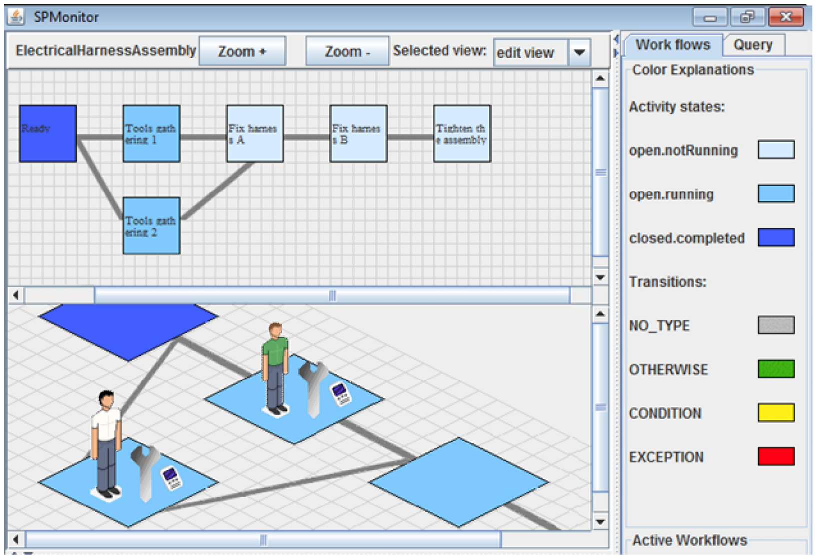

FIGURE 4: Visualisation views representing the monitored workflow

In the domain of aircraft manufacturing, work orders are often so complex that they cannot be expressed with single-level workflows and thus multi-level work processes must be utilised. In multi-level work processes, workflows contain activities that comprise a workflow of their own. These sub-workflows define the tasks that must be performed inside an individual main-workflow activity in order to complete it. Additionally, several operators may be assigned to a single workflow, which demands that activities are performed in parallel. In order to address these challenges, the functionalities of SPMonitor were designed to support the monitoring of workflows that include numerous of sub-workflows and various operators. For example, when a monitored workflow proceeds to an activity that launches a sub-workflow, SPMonitor automatically opens that sub-workflow to be monitored in a currently active visualisation view

4.1 The Management of Unexpected Events

An important part of the EADS scenario is the treatment of an unexpected event during the process. First, SPMonitor must dynamically inform the actors concerned about an occurrence of an anomaly and second, it must provide the means to recover from a problem situation. The sequence diagram presented in Figure 5 illustrates the interaction between SPMonitor and the support team in the scenario.

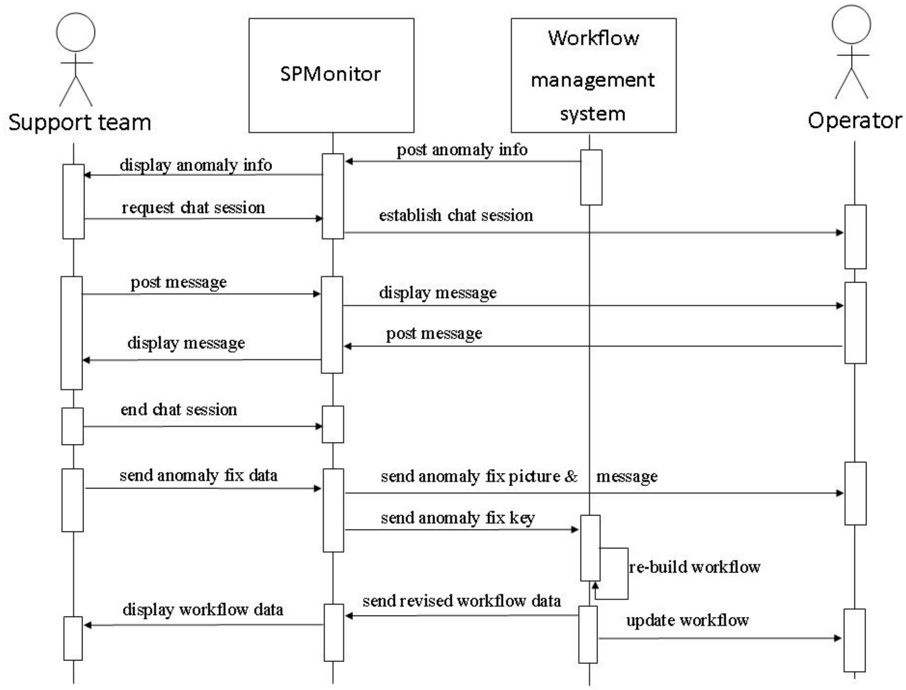

FIGURE 5: The sequence diagram for anomaly management

To facilitate the interaction between various actors involved, SPMonitor defines an interface element that enables the workflow engine to send a notification about unexpected events. The notification contains the necessary information for addressing different problems. Additionally, SPMonitor includes various communication features and problem-solving functionalities that assist users in managing unexpected events. For example, the support team is able to dynamically modify process definitions at run-time.

Any anomalies that occur are usually managed in cooperation with operators and a support team. SPMonitor enhances the cooperative work by disseminating information about anomalies and providing communication mechanisms to exchange data between employees. In the example scenario an operator notices that an earth wire is missing and thus decides to interrupt the procedure as it cannot be finished properly. The operator is also able to describe the problem in more detail by writing an anomaly message using the nomadic device.

In SPMonitor, the anomaly is indicated by representing the involved activity in red and opening an anomaly information dialogue. The anomaly information dialogue contains such necessary details about the unexpected event as the activity in which the anomaly occurred, a descriptive picture and the message that the operator has written. If the support team perceives that the data contained by the anomaly information dialogue is inadequate, it can start a chat session with the operator to acquire more details about the problem. SPMonitor establishes the chat connection with the operator's PDA device by using a communication middleware solution.

Once the support team has enough information about the anomaly, it can decide how to proceed with the task orders. If the support team feels that the assembly process can be completed despite the anomaly, it can informally advise the operator on how to work around the problem and press the 'Proceed' button in the anomaly information dialogue. However, if the unexpected event prevents the workflow from proceeding, the support team can interrupt the workflow by pressing the 'Stop workflow' button. In this case, the support team will usually need to completely redesign the process definition with the workflow management system.

The final option is to dynamically redesign the workflow using the communication capabilities of SPMonitor. In that case, the support team defines a ‘fix key’ that indicates to the workflow management system how the problem can be resolved in run-time. Besides the fix key, the support team defines a descriptive picture and a textual message that guide the operator in solving the problem. The information is transmitted to the workflow management system that re-directs the descriptive picture and the message to the operator’s nomadic device and adds a complementary activity into the workflow. In this case, the new activity is called “Fix earth wire”. Subsequently, it notifies SPMonitor of the changes in the workflow so that the monitor visualisation can be updated. The data flows between the operators and the support team is illustrated in Figure 6.

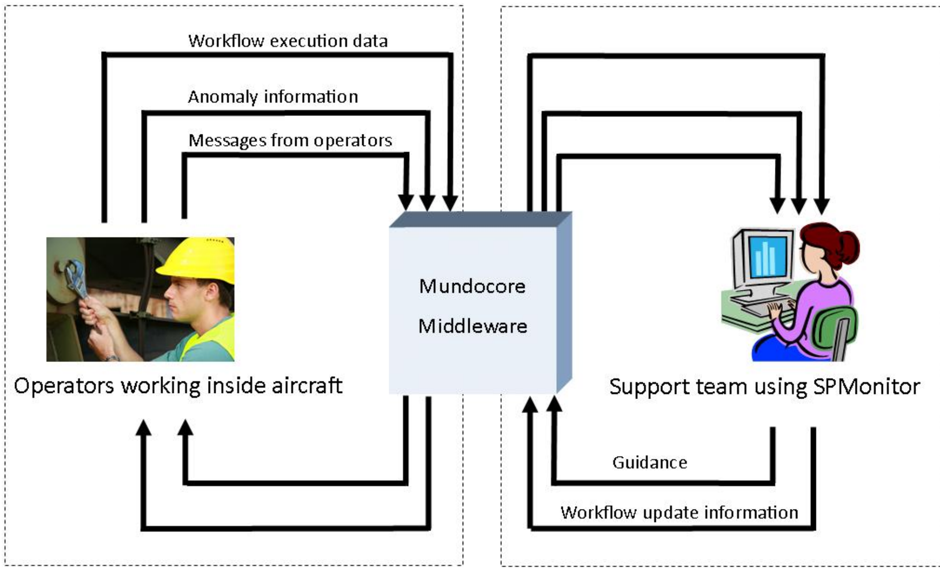

FIGURE 6: Data flows between the operators and the support team

5. EVALUATION

SPMonitor aims at supporting cooperation work by enabling the remote monitoring of workflows proceedings and providing communication mechanisms to exchange information among different actors. The tool also provides interactive means to acquire additional information about workflow activities and react to unexpected events during processes. Due to the purpose of the tool, we think that usability and the perceived usefulness are the most important characteristics to be evaluated. Apart from evaluating the usability of the tool, we were interested in obtaining evaluation results regarding the acceptance of the SPMonitor as new technology in the aircraft assembly processes.

According to the Technology Acceptance Model (TAM) [26], a number of factors influence users’ decisions about how and when they will use new technology. These are ‘perceived usefulness’ defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" and ‘perceived ease-of-use’ defined as "the degree to which a person believes that using a particular system would be free from effort". A six-indicator measurement for the usefulness of technology using the example of email was introduced by Davis. In our evaluation we reused some of these metrics.

For the evaluation we used an empirical usability testing approach, which relied mainly on the coaching method, thinking aloud protocol [27] and post-test questionnaires constructed to mirror the usability measurement discussed above, and secondly a focus group method [28]. The focus group comprised seven researchers with heterogeneous experience in workflow management, semantic knowledge modelling, services and support tools.

The practical implementation of the evaluation followed the aircraft manufacturing scenario, in which the electrical assembly procedure is presented from the planning stage to its certification, including the treatment of an unexpected event during the process. For the empirical usability testing, the researchers, usability specialists and domain experts from EADS were invited to participate. The test was started by clarifying the goals, objectives and intended purpose of use of SPMonitor. Instructions for completing the test tasks were also given on paper so those involved in the test could familiarise themselves with the tasks before starting the test. After the introduction of software, the participants were asked to perform the aircraft manufacturing scenario related tasks with SPMonitor.

First of all, the empirical usability testing gave us confirmation that SPMonitor is considered a useful tool by its end users and that the chosen visualisation techniques are suitable for monitoring workflows. In addition, the provided interaction functionalities were seen as adequate by the test participants. For example, a test participant from EADS estimated that the chat feature is sufficient for resolving 90% of the encountered problems. At the same time, usability testing revealed some ideas on how to improve the tool. For example, the distinction between main workflows and sub-workflows should be clearer in the visualisations. The activities that contain sub-workflows should be represented more explicitly and more general views representing hierarchy levels of different workflows should be provided. Another feature that received some criticism was the anomaly information dialogue. It was suggested that the dialogue should provide more detailed information about the unexpected event. Finally, participants felt that the graphical user interface should indicate more clearly those activities which were being performed in parallel.

In the final phase of the test process, the test participants were asked to fill out a questionnaire, which included questions related to the perceived ease-of-use and usefulness of the tool. The questionnaire contained both questions on a Likert scale from 1-5 and open questions requiring a written answer. Figure 7 presents the average response levels with numerical answers.

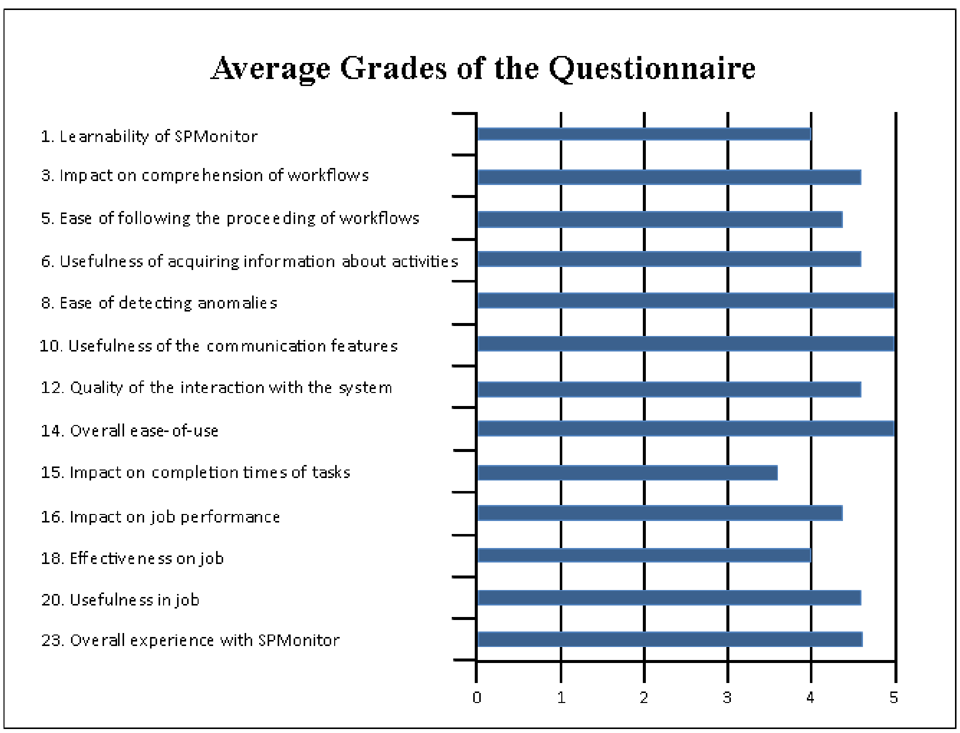

FIGURE 7: The results of the questionnaire

As can be seen the overall response level is quite high. Only statement number 15 has an average grade of below 4. One of the objectives of SPMonitor is to provide time savings in aircraft manufacturing processes, especially by enhancing anomaly management procedures. Apparently, some of the test participants were not convinced that they could save a substantial amount of time in dealing with unexpected events by using SPMonitor. On the other hand, it may have been difficult for test participants to provide any accurate estimates of how much time the system would save them, as some of them were not the intended end users of the approach they evaluated. The written responses also reflected the positive reception of SPMonitor, as they included many encouraging comments. For example, one participant stated that “It’s an interesting tool to present to EADS business units”. These kind of comments increase the motivation to further develop the tool.

The feedback obtained from the focus group session gave us many fresh ideas for future research work and the development of SPMonitor. For example, many of the focus group members suggested that SPMonitor could be useful in the domain of project management. A concrete use case example is monitoring the progress of a software development project in order to see the current state of different tasks and examining potential problems that may come up. Potential was also seen in using the tool in project planning, where SPMonitor could enhance such tasks as project configuration and resource assignment. Finally, the focus group suggested numerous other domains in which SPMonitor could be useful. These domains include education, real estate maintenance and health care.

Many of the focus group session participants also considered that SPMonitor could use the capabilities provided by semantic technologies more effectively. Currently, SPMonitor stores data related to past workflows, which enables the performance of sophisticated analysis and diagnostics reports. Thus it supports the design phase of workflows, by enabling to better estimate how long the execution of workflows with certain types of activities, transitions and resources (e.g. tools and operators) will take and what kind of anomalies can be expected. However, if the tool were to use the powerful reasoning capabilities provided by semantic technologies more efficiently, it could dynamically produce more sophisticated analysis containing information describing issues such as data dependencies of a workflow in run-time. Additionally, the more efficient utilisation of semantic technologies could improve the SPMonitor’s ability to deal with unexpected events.

Although, the evaluation carried out in this study gave some insight into the potential of the tool, it must be borne in mind that the actual verification of the approach can only be done in a real production environment where the way in which the approach copes with the demanding requirements of final aeronautical assembly lines can be tested. The feedback provided by end users is also likely to provide a more accurate picture of the usefulness of the tool, as they have more experiences from using the approach. Moreover, the testing in a real production environment will facilitate the gathering of quantitative data, which will provide more accurate information on how much time SPMonitor actually saves, or whether it has an impact on the occurrence rate of anomalies, for example.

6. CONCLUSIONS AND FUTURE WORK

Digital means and computer-supported collaboration techniques are being used widely in engineering in many production domains. It is adopted in particular in the modelling and simulation of the manufacturing processes in large industrial companies. However, the monitoring and visual support to facilitate the coordination functions of run-time productive environments is still a challenge.

In this paper, we have proposed semantically empowered visualisation aids to support collaborative processes and corrective decision-making for various actors, such as operators, support teams and station managers involved in the execution of the productive process. The resulting approach dynamically visualises information related to workflows, including the processes, participants and other resources involved. An important aspect is also to show illustratively the possible anomalies that may occur during a workflow and allow users to react more efficiently to the problems. The ability to provide a "global view" of workflows improves the overall comprehension of processes and allows users to gain a better overall picture of the whole ecosystem.

The approach also specifies a new workflow ontology that defines concepts, relationships and attributes needed for describing workflows and other related information. The semantic modelling and processing of workflows has many benefits as it enables more sophisticated diagnosis and analysis possibilities, and also facilitates more efficient run-time decision-making capabilities. Moreover, the use of semantic technologies enhances the integration of heterogeneous workflow-related information into a single data model. However, the utilisation of semantic technologies also presents a challenge and therefore further research must be carried out on how to better exploit the full potential they offer. Additionally, more information regarding what kind of diagnostics and analysis information would be most useful for end users should be acquired from domain experts.

The approach has been validated within the actual application and use cases associated with final aeronautical assembly lines. The evaluation was carried out in two phases: firstly a focus group session was organised and secondly, analytical user tests were performed. The focus group session provided numerous suggestions on possible directions in which the tool could be developed. The analytical user tests provided information on the system's ability to meet its requirements in terms of usability and perceived usefulness. Through the light evaluation performed in this stage, SPMonitor has demonstrated its potential in terms of the improvement of productivity, flexibility and product quality. However, a thorough verification of the tool would require more extensive testing in a final production environment.

Apart from the aeronautical domain, we believe the tool can also bring about benefits to other application domains such as logistics, education, real estate maintenance and health care, thanks to the extensible capabilities of the tool in terms of domain-specific ontologies and additional visual graphics libraries.

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FAX: 006 03 6207 1697
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